U. S. DEPARTMENT OF ENERGY

FIELD WORK PROPOSAL

1. WORK PACKAGE NO.:	1a. WORK PROPOSAL NO.:	2. REVISION NO.:	3. DATE PREPARED	3a. CONTRACTOR NO.:
			10-11-05	R5NoFS

4. WORK PACKAGE TITLE:	4a. WORK PROPOSAL TITLE:
Nuclear Physics	Studies and Comparisons of Alternative Fragment Separator Layouts

5. BUDGET & REPORTING CODE:	6. WORK PROPOSAL TERM: Begin: End:	7. IS THIS WORK PACKAGE INCLUDED IN THE INST. PLAN?	7a. PRINCIPAL INVESTIGATORS:
KB-04-01			J. Nolen

8. HEADQUARTERS/OPERATIONS OFC PROGRAM MANAGER: Kovar, D. G. (301) 903-3613	11. HEADQUARTERS ORGANIZATION: Office of Science	14. DOE ORG. CODE: SC
9. OPERATIONS OFFICE WORK PROPOSAL REVIEWER:	12. OPERATIONS OFFICE: Chicago	15. DOE ORG. CODE: CH
10. CONTRACTOR WORK PROPOSAL MANAGER: Geesaman, D. F. (630) 252-4004	13. CONTRACTOR NAME: University of Chicago/ANL	16. CODE: 12

17. IS THIS PROPOSAL TO DO WORK THAT INCLUDES A SECURITY INTERES? ☐ YES ☒ NO

18. WORK PROPOSAL DESCRIPTION (Approach, anticipated benefit in 200 words or less):

This proposal is being submitted in response to the call entitled "LAB 05-22, Research and Development for the Rare Isotope Accelerator" issued by the DOE Office of Science.

Summary/abstract:

The RIA Fragment Separators are core components of the facility, linking the production of isotopes with heavy ion primary beams to the experimental areas. Their purpose is to separate products of interest from the primary beam and unwanted products, and deliver the wanted products to experimental stations. It also must contain the primary beam and radioactive contaminants. The collection of the largest possible amount of selected isotopes and delivery in an identifiable form to experiments puts stringent constraints on the separator's performance, and requires a careful design and optimization.

By the end of the FY05 research on this topic, we will have in place all the building blocks to undertake an end-to-end simulation of the whole system. The required beam-material interactions and corresponding nuclear processes will be implemented in a state-of-the-art nonlinear beam dynamics simulation code, COSY INFINITY. This integrated approach to nuclear physics and beam optics will lead to a simulation and design environment with some unique features, not available in any other code around the world. The simulations will allow to study not only the performance of the system in terms of resolution, selection purity, yields of wanted products, etc., but also the background particles' distribution, optimal target thicknesses, optimal shape of the absorbers, and so on.

19. CONTRACTOR WORK PROPOSAL MANAGER:		20. OPERATIONS OFFICE REVIEW OFFICIAL:	
SIGNATURE D. F. Geesaman	DATE 10-11-05	SIGNATURE	DATE 10-11-05

21. DETAIL ATTACHMENTS: (See instructions.) Task Proposals Attached.

☒ a Facility requirements	☒ d. Background	☒ g. Future accomplishments	☒ j. Explanation of milestones
☒ b. Publications	☒ e. Approach	☒ h. Relationships to other projects	☒ k. Human or Animal Subjects Activities
☒ c. Purpose	☒ f. Technical progress	☒ i. Environmental assessment	☒ l. Other (specify): ES&H

WORK PROPOSAL REQUIREMENTS FOR OPERATING/EQUIPMENT OBLIGATIONS AND COSTS

CONTRACTOR NAME	WORK PROPOSAL NO.	REVISION NO.	CONTRACTOR NO.	DATE PREPARED
University of Chicago/ANL	R6NoFS		56401	10-11-05

21. STAFFING (in staff years)	PRIOR YEARS	FY 2006	FY 2007		FY 2008		FY 2008	FY 2009	TOTAL TO COMPLE
			ESTIMATE	REVISED	REQUEST	AUTHORIZ			
a. SCIENTIFIC		0.1							
b. OTHER DIRECT		0.0							
c. TECHNICAL SERVICES*................		0.0							
d. TOTAL DIRECT		0.1							
22. OBLIGATIONS AND COSTS (in thousands)									
a. TOTAL OBLIGATIONS....................		$312							
b. TOTAL COSTS		$312							
23. EQUIPMENT (in thousands)									
a. EQUIPMENT OBLIGATIONS..........									
b. EQUIPMENT COSTS......................									

24. MILESTONE SCHEDULE (Tasks)	FY 2006 DOLLARS		PROPOSED SCHEDULE	AUTHORIZED SCHEDULE
	PROPOSED	AUTHORIZED		

25. REPORTING REQUIREMENTS

*Technical services staffing includes ANL support divisions' scientific effort.

Cover page

TITLE OF PROPOSED RESEARCH: Studies and Comparisons of Alternative Fragment Separator Layouts

DOE Office of Science Program Announcement: Research and Development for the Rare Isotope Accelerator, LAB 05-22

NAME OF LABORATORY: Argonne National Laboratory

PRINCIPAL INVESTIGATOR:

Dr. Jerry Nolen, Senior Physicist
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
Phone/Fax: 630-252-6418 / 630-252-8400
Email: Nolen@anl.gov

Signature of Principal Investigator:

______________________________________Date_________________

CERTIFICATION OF AVAILABILITY OF PERSONNEL AND FACILITIES AS STATED IN THE PROPOSAL:

Dr. Donald F. Geesaman, Director, Physics Division
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439
Phone/Fax: 630-252-4004 / 630-252-3903
Email: geesaman@anl.gov

Signature of Certifying Representative:

___________________________________Date_________________

REQUESTED FUNDING (1-year project period): FY 2006: $312k

USE OF HUMAN SUBJECTS IN PROPOSED PROJECT: No

USE OF VERTEBRATE ANIMALS IN PROPOSED PROJECT: No

STUDIES AND COMPARISONS OF ALTERNATIVE FRAGMENT SEPARATOR LAYOUTS

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STUDIES AND COMPARISONS OF ALTERNATIVE FRAGMENT SEPARATOR LAYOUTS

Principal Investigators: J. Nolen, Physics Division, ANL
B. Erdelyi, Physics Division, ANL & Northern Illinois University
K. Makino, Michigan State University

Collaborators: T. Barlow, I.C. Gomes Consulting & Investment Inc.
M. Berz, Michigan State University
B. Sherrill, Michigan State University

Abstract

The RIA Fragment Separators are core components of the facility, linking the production of isotopes with heavy ion primary beams to the experimental areas. Their purpose is to separate products of interest from the primary beam and unwanted products, and deliver the wanted products to experimental stations. It also must contain the primary beam and radioactive contaminants. The collection of the largest possible amount of selected isotopes and delivery in an identifiable form to experiments puts stringent constraints on the separator's performance, and requires a careful design and optimization.

By the end of the FY05 research on this topic, we will have in place all the building blocks to undertake an end-to-end simulation of the whole system. The required beam-material interactions and corresponding nuclear processes will be implemented in a state-of-the-art nonlinear beam dynamics simulation code, COSY INFINITY. This integrated approach to nuclear physics and beam optics will lead to a simulation and design environment with some unique features, not available in any other code around the world. The simulations will allow to study not only the performance of the system in terms of resolution, selection purity, yields of wanted products, etc., but also the background particles' distribution, optimal target thicknesses, optimal shape of the absorbers, and so on.

Narrative

Background and Significance

The Fragment Separators of the RIA are critical and challenging components that have been identified as high priority for R&D. Specific topics requested in this solicitation are being addressed by the present collaboration in this proposal and a companion proposal from the NSCL.

The fragment separators for the RIA will be placed after the ion linac, where the primary beams of any species from proton to uranium are accelerated to up to 1 GeV for protons and 400 MeV/u for uranium. The high energies make possible the utilization of thick production targets, and the creation of a wealth of rare isotopes of interest for the experimental stations.

The fragment separators' role is to collect, separate, and deliver the desired isotopes to a variety of experimental stations. The main production mechanisms are the above mentioned fragmentation by incoming heavy-ion projectiles of high energy, and the in-flight fission of the uranium. The production kinematics being different, the fragment separators must be designed with a large acceptance in both momentum and angular spread. Also, the high primary beam power requires the consideration of the optimal choice, location, and placement of a high power beam dump. Also, the success of the experiments depends on the purity of the separated isotopes. This requires large resolving powers. The large acceptance and transmission requirements imply the use of large aperture superconducting magnets.

The isotopes are impossible to separate by magnetic and/or electric fields only. The separation method envisioned is the so-called $B\rho$-ΔE-$B\rho$ method, i.e. a double rigidity analysis (that is roughly proportional to mass over charge ration if the velocity spread is negligible) and an intermediate atomic energy loss through a piece of material. An important aspect to be studied is the interplay of the high order optics design and aberration correction needed for high resolving powers with the beam-material interactions. This requires an integrated approach to the nuclear processes inherent when a beam is passing through some material and the beam dynamics of the resulting beam of particles. This proposal is a continuation of a grant with the same title for FY05, where such a programming, design, and simulation framework is being established.

The large acceptance, aperture, transmission, and beam parameter spreads require the use of codes that permit precision modeling of the beam dynamics, namely the inclusion of fringe field effects, high order aberrations, and trajectories of charged particles passing through material. Collaboration with other groups using different simulation tools will allow meaningful comparison of alternate designs and layouts, including code benchmarking.

The topics we propose to study were identified in this solicitation as high priority for RIA related R&D, more specifically:

- Development of fragment separator simulation codes for the collection, separation, and stopping process, including the process to verify these codes
- Evaluation of beam dumps, including simulations of the beam dump locations
- Determination by detailed simulations the limitations of the range bunching technique and the optimum energies for range bunching
- Evaluation of the matching of the separator, gas cell, and post-acceleration stages

Preliminary Studies

COSY INFINITY is an arbitrary order beam dynamics simulation and analysis code. It allows the study of accelerator lattices, spectrographs, beam lines, electron microscopes, fragment separators, and many other devices. It can determine high-order maps of combinations of particle optical elements of arbitrary field configurations. The elements can either be based on a large library of existing elements with realistic field configurations including fringe fields, or described in detail by measured data. Analysis options include computation of high-order nonlinearities; analysis of properties of repetitive motion via chromaticities, normal form analysis, and symplectic tracking; analysis of single-pass systems resolutions, reconstructive aberration correction, and consideration of detector errors. COSY has its own object oriented programming language, and a differential algebra based computation engine. It includes optimization commands at the language level. It has been used in the design and modeling of various systems. Its features make it the ideal code for precision modeling, design, and optimization of the RIA fragment separators.

Initial studies have been carried out for the fragment separators, using COSY Infinity and two possible layouts: one based on 30 degree dipoles preceded and followed by quadrupole triplets, and another based on 35 degree dipoles preceded and followed by quadrupole doublets. Following a first order design, an order by order aberration correction up to third order has been attempted, with the purpose of optimizing acceptance, resolving power, transmission, and finding a suitable location for the beam dump. In the following we summarize our preliminary findings.

Doublet system

We split the “missing” quadrupole in our initial triplet layout from our previous year proposal among the other two quadrupoles to form a doublet, and set all quadrupole apertures to 20 x 40 cm. Beside the space freed up for the beam dump, as a side effect we noticed that an increase in resolving power is achieved. Figures 1 and 2 show the horizontal and vertical beam envelopes, respectively. In this case the slight reduction in the transmission (73.7% for the doublet system) is more than compensated by the increased resolving power, resulted from a dispersion of 2.32 cm/% energy using the same beam.

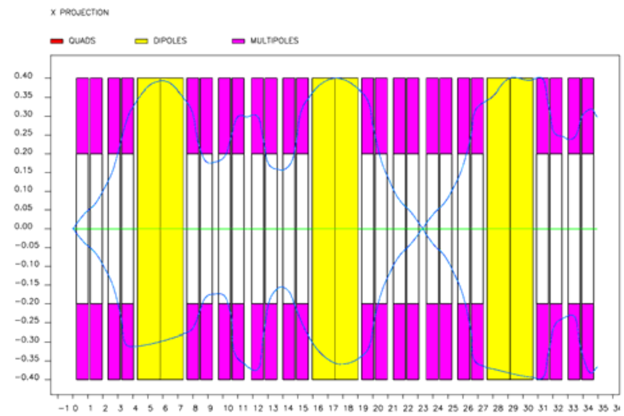

Figure 1. Horizontal envelope of the doublet system

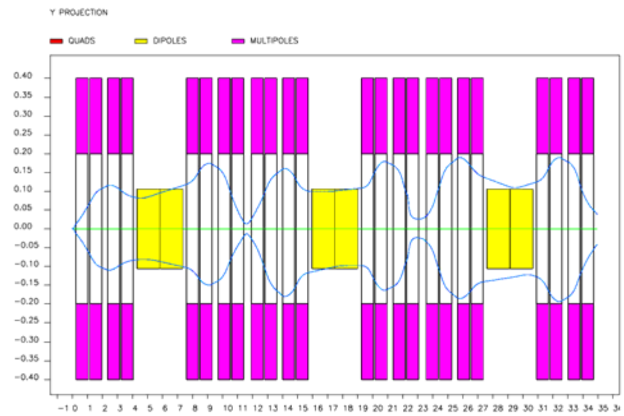

Figure 2. Vertical envelope of the doublet system

Search for a new layout based on symmetries

A simple yet high quality imaging system is needed for the Rare Isotopes Accelerator's fragment separator. The fragment separator must contain a dispersive image and an achromatic image with aberrations minimized to less than 1 mm in the spatial directions. Different theories of symmetries were examined to find ways to minimize 2^{nd} and 3^{rd} order aberrations while forming the desired images. Symmetries examined are: time-independence symmetries, midplane symmetry, mirror symmetry, and symplectic symmetry. The mirror symmetry with respect to the dispersive image plane ensures a high quality achromatic image at the end. We gave prescriptions that describe how to apply the symmetries. These symmetries are very useful and can be applied to a wide variety of systems to remove and minimize harmful higher order aberrations.

In summary, by applying the time-independence "symmetries" nearly 30% of the map coefficients are removed. Applying midplane symmetry removes about half of the transfer map elements that are left. The commutator map up to the dispersive image plane contains 5 1^{st} order, 15 2^{nd} order, and 35 3^{rd} order elements that need to be minimized. Applying symplectic symmetry reduces the number of commutator elements that need to be minimized. Five 1^{st} order elements still need to be minimized. The number of 2^{nd} order and 3^{rd} order elements that need to be reduced have been reduced to 10 and 21 respectively. For more details, see *J. Brady and B. Erdelyi, Using Symmetries to Cancel Aberrations in the RIA Fragment Separators*.

Integrated approach to nuclear processes and beam dynamics

By the end of the FY05 research on this topic, we will have in place all the building blocks to undertake an end-to-end simulation of the whole system. The required beam-material interactions and corresponding nuclear processes will be implemented in a state-of-the-art nonlinear beam dynamics simulation code, COSY INFINITY. This integrated approach to nuclear physics and beam optics will lead to a simulation and design environment with some unique features, not available in any other code around the world.

The functionalities of a suite of nuclear physics codes are now available in COSY. These include fragmentation cross-sections via the EPAX parameterization, charge state evolution based on the GLOBAL code, energy loss via ATIMA spline interpolation, and angular and energy straggling based on the Linhard-Sorensen (LS) theory and appropriate corrections as implemented in ATIMA.

A new element, ABSORBER, is now available in COSY that makes possible following a beam distribution in an arbitrarily shaped piece of absorber, and gives the outgoing beam's distribution, including what kind and how many isotopes have been created, where they are located in phase space, and what is their charge state. This includes not only the isotopes of interest, but also what is left of the primary beam, background particles, effects of multiple fragmentations, etc.

The new tool is in the debugging stages. For benchmarking the distribution of newly created particles against the codes MOCADI in use at GSI and LISE in use at NSCL we are testing the fraction left of primary beams, the distribution of fragments, the relative importance on the yields of specific isotopes in one-step and multiple-step fragmentation processes, among other things. We are hoping that the tool will be ready soon for production runs in Monte-Carlo mode.

In the map mode, where the deterministic part of the motion is taken into account, the absorber element includes only the energy loss, and the arbitrary shape of the absorbing material. Once the absorbing material and its shape, determined by polynomial functions of its entrance and exit shapes, are specified, its effect will be concatenated with the rest of the system, resulting in a transfer map for the whole fragment separator. This approach allows powerful fast optimization of the system, including the deterministic aspects of the wedges. Right now, the absorber's energy loss is described by the Bethe-Bloch formula.

Research Design and Methods

Research Description

In summary, the proposed program can be split into two main parts:

- **Perform end-to end studies by utilizing the map-based capabilities** of the environment for the optics design, where only the deterministic part of the system is taken into account (including absorbers),
- **Perform Monte-Carlo type end-to-end studies**, in which the results from part one is incorporated and the effect of stochastic processes are evaluated.

We envision an iterative process in which the interplay between deterministic and stochastic processes is evaluated in part two, and the system re-optimized in part one based on what we learn in the Monte-Carlo studies. The simulations will allow to study not only the performance of the system in terms of resolution, selection purity, yields of wanted products, etc., but also the background particles' distribution, optimal target thicknesses, optimal shape of the absorbers, and so on.

We propose to continue to study and improve the doublet system, and to search for alternate designs with better performance in terms of acceptance, transmission, and resolving power, and to take into account engineering constraints too. We will apply the symmetry-based theory in searching for practically feasible fragment separator designs with intrinsically low aberration content. This would make the correction of high order harmful aberrations easier. As the basic building block of such a system, a point-to-point and parallel-to-parallel imaging system in both horizontal and vertical planes would be desirable.

The requirements for the fragment separators make the correction of aberrations up to 5th order necessary. The newly extended code COSY Infinity has some unique capabilities that we need to address this issue. It allows us to compute and analyze any system up to high orders, and optimize it according to the requirements in a flexible, comprehensive, and integrated way. Moreover, it has the capability to model the dynamics with very high precision, including variation of fields longitudinally, especially in the end regions of the magnets. The code can be run in two modes: map-based for optimization of the deterministic part of the motion, and a hybrid map-Monte-Carlo-based for stochastic effects. We intend to study the matching of wedge shapes to maintain high resolving power for each selected isotope, and absorber shape for optimized range-bunching. Optimal target material and thickness will be studied to maximize the yields of selected isotopes, with multiple fragmentations taken into account.

To achieve this task we expect that further code development will be necessary to address the issues as they arise. To this end, we will consider the advantages of exploiting the parallel version of the code, which now is being tested at NERSC. The parallel version would also enable optimization in the Monte-Carlo context. The power of the optimization in the parallel Monte-Carlo context would be maximized by the use of parallel optimizers. There are initiatives, at ANL and elsewhere, to explore parallel optimization algorithms, that would directly benefit the future research presented in this proposal. Once an algorithm has been selected, it can be implemented in COSY and applied to fragment separator optimization, a topic that hopefully will be addressed in future proposals.

References

B. Blank, J.-J. Gaimard, H. Geissel, G. Münzenberg, K.-H. Schmidt, H. Stelzer, K. Sümmerer, H.-G. Clerc, E. Hanelt, B. Voss, D. Bazin, R. Del Moral, J.-P. Dufour, A. Fleury and M.S. Pravikoff, “First Application of the Momentum-Loss Achromat to the Isotopic Separation of Relativistic Projectile Fragments,” Nucl. Instr. and Meth. in Phys. Res. A286 (1990) 160

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M. Berz. “Modern Map Methods in Particle Beam Physics,” Academic Press (1999).

K. Makino, M. Berz, D. Errede, and C. J. Johnstone. “High Order Map Treatment of Superimposed Cavities, Absorbers, and Magnetic Multipole and Solenoid Fields,” NIM **A519** (2004) 162-174.

C. Rosenthal, B. Erdelyi, Modeling and Visulaizing the Particle Beam in the Rare Isotope Accelerator, submitted to the Journal of Young Investigators (2005)

J. Brady, B. Erdelyi, Using Symmetries to Cancel Aberrations in the RIA Fragment Separators, report of summer 2005 research internship at ANL, to be submitted.

Budget pages and explanation

The budget for this proposal is dominated by manpower from the three institutions, ANL, NIU, MSU, and I.C. Gomes Consultants. The total budget is $312k.

The allocations of effort and cost are:

ANL: 1 FTE-month for Jerry Nolen, plus $3k for meeting and workshop travel.

NIU: 6 FTE-months for Bela Erdelyi and support for a PhD student via a sub-contract for $100K.

MSU: 2 FTE-months for Kyoko Makino, 1 FTE-month for Martin Berz, and 4 months of support for a PhD student via a sub-contract for $60K which includes a $3K travel and $4K miscellaneous M&S allocation.

I.C. Gomes Consultants: 8 FTE-months for Teresa Barlow via a sub-contract for $90K.

There will be several meetings and workshops held during FY2006 with the participation of this group, the NSCL group led by Brad Sherrill (see the letter of intent), and the GSI Fragment Separator Group led by Hans Geissel. In a larger workshop the RIKEN group will also participate.

R6NoFS

DOE F 4620.1 (edited for RIA R&D proposals)
(04-93)
All Other Editions Are Obsolete

U.S. Department of Energy

Budget Page

(for ANL)

OMB Control No.
1910-1400
OMB Burden Disclosure
Statement on Reverse

Studies and Comparisons of Alternative Fragment Separator Layouts

ORGANIZATIONS: Argonne National Laboratory

Budget Page No: 1 for FY-2006

PRINCIPAL INVESTIGATOR/PROJECT DIRECTOR: Dr. J. Nolen

Requested Duration: 12 (Months)

A. STAFF SCIENTIFIC PERSONNEL: PI/PD, Co-PI's, Faculty and Other Senior Associates	DOE Funded FTE-mos.	ANL Funds Requested by Institution	Funds Requested by Institution	Funds Requested by Institution
1. J. Nolen	1.0	$ 7,604		
2.				
3.				
4.				
5.				
6. ( ) OTHERS (LIST INDIVIDUALLY ON BUDGET EXPLANATION PAGE)				
7. (1) TOTAL STAFF SCIENTIFIC PERSONNEL (1-6)	1.0	$ 7,604		
B. OTHER PERSONNEL (SHOW NUMBERS IN BRACKETS)				
1. ( ) POST DOCTORAL ASSOCIATES				
2. ( ) OTHER PROFESSIONAL (TECHNICIAN, ENGINEER, ETC.)				
3. ( ) GRADUATE STUDENTS				
4. ( ) UNDERGRADUATE STUDENTS				
5. ( ) SECRETARIAL - CLERICAL				
6. (X) OTHER DIVISIONAL/DEPARTMENTAL OVERHEAD		$ 5,586		
TOTAL SALARIES AND WAGES (A+B)		$ 13,190		
C. FRINGE BENEFITS (IF CHARGED AS DIRECT COSTS)		$ 2,677		
TOTAL SALARIES, WAGES AND FRINGE BENEFITS (A+B+C)		$ 15,867		
D. PERMANENT EQUIPMENT (LIST ITEM AND DOLLAR AMOUNT FOR EACH ITEM.)				
TOTAL PERMANENT EQUIPMENT				
E. TRAVEL				
1. DOMESTIC (INCL. CANADA AND U.S. POSSESSIONS)		$ 1,000		
2. FOREIGN		$ 2,000		
TOTAL TRAVEL		$ 1,000	$ -	$ -
F. TRAINEE/PARTICIPANT COSTS				
1. STIPENDS (Itemize levels, types + totals on budget justification page)				
2. TUITION & FEES				
3. TRAINEE TRAVEL				
4. OTHER (fully explain on justification page)				
TOTAL PARTICIPANTS ( ) TOTAL COST				
G. OTHER DIRECT COSTS				
1. MATERIALS AND SUPPLIES				
2. PUBLICATION COSTS/DOCUMENTATION/DISSEMINATION				
3. CONSULTANT SERVICES				
4. SERVICE REQUESTS (ANL IN-HOUSE)				
5. SUBCONTRACTS (NIU, MSU, I. C. Gomes)		$ 250,000		
6. OTHER Misc M&S costs		$ 70		
TOTAL OTHER DIRECT COSTS		$ 250,070		
H. TOTAL DIRECT COSTS (A THROUGH G)		$ 266,937		
I. INDIRECT COSTS (SPECIFY RATE AND BASE)				
29.3% Indirect Cost on Service Requests	ANL	$ -		
35.8% Indirect Cost on Effort, Fringe, Overhead & Misc M&S	ANL	$ 6,063		
15.6% Indirect Cost on Procurements & Sub-contracts	ANL	$ 39,000		
TOTAL INDIRECT COSTS		$ 45,063		
J. TOTAL DIRECT AND INDIRECT COSTS (H+I)		$ 312,000		
K. AMOUNT OF ANY REQUIRED COST SHARING FROM NON-FEDERAL SOURCES				
L. TOTAL COST OF PROJECT (J+K)		$ 312,000		

Biographical Sketch 1

Jerry A. Nolen, Jr.
Physics Division
Argonne National Laboratory

DATE OF BIRTH: November 17, 1940

DEGREES AWARDED:

B.S., Engineering Physics, Lehigh University	1961
Ph.D., Physics, Princeton University	1965

HONORS:

Lehigh University: B.S. with Highest Honors
Tau Beta Pi (President, Lehigh Chapter 1960-1961)
Pi Mu Epsilon
Phi Beta Kappa
Sigma Xi
Woodrow Wilson Fellow (1961-1962)
Fellow, American Physical Society (1984)

APPOINTMENTS:

1992-present:	Director of ATLAS and Senior Scientist, Physics Division, Argonne National Laboratory, Argonne, IL, Technical Director of RIA at Argonne (since 2003), and Adjunct Professor of Physics, Michigan State University.
1982-1992:	Associate Director, NSCL - Research Facilities, Michigan State University
1977:	Fellow, Max Planck Institute, Heidelberg, Germany
1976-1992:	Professor of Physics, Michigan State University
1974:	Visiting Associate Professor, Princeton University
1970-1976:	Associate Professor of Physics, Michigan State University
1968-1970:	Assistant Professor of Physics, University of Maryland
1966-1968:	Postdoctoral Appointment, Argonne National Laboratory
1965-1966:	Instructor, Princeton University

Jerry A. Nolen, Jr.

Selected Recent Publications

B.M. Sherrill, D.J. Morrissey, J.A. Nolen, Jr., and J.A. Winger, “The A1200 Projectile Fragment Separator,” Nucl. Instr. Meth. **B56/57** (1991).1106

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A. A. Geraci, T. A. Barlow, M. Portillo, J. A. Nolen, K. W. Shepard, K. Makino, and M. Berz, “High-Order Maps with Acceleration for Optimization of Electrostatic and Radio-Frequency Ion-Optical Elements,” Rev. Sci. Instrum. **73** (2002) 3174-3180.

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Biographical Sketch 2

Bela Erdelyi
Physics Department
Northern Illinois University
Physics Division
Argonne National Laboratory

DATE OF BIRTH: February 07, 1968

DEGREES AWARDED:

Ph.D., Physics, Michigan State University	2001
B.S., Physics, Babes-Bolyai University, Romania	1993

APPOINTMENTS:

2004 – present	Joint Appointment: Assistant Professor Department of Physics, Northern Illinois University Assistant Physicist Physics Division, Argonne National Laboratory
2001-2004	Research Associate Fermi National Accelerator Laboratory

PUBLICATIONS:

23. *Beam-Beam Effects at the Fermilab Tevatron: Theory*, with T. Sen, Phys. Rev. -STAB **7** (2004) 041001

22. *Local Theory and Applications of Extended Generating Functions*, with M. Berz, International Journal of Pure and Applied Mathematics **11**, 3 (2004) 241-282

21. *Rigorous Lower Bounds for the Domains of Definition of Extended Generating Functions*, with J. Hoefkens and M. Berz, accepted for publication in SIAM Journal of Applied Dynamical Systems (2003)

20. *Tracking of Three Variants of Transition-Free Lattices for a Proton Driver*, 20th Proceedings of ICFA Advanced Beam Dynamics Workshop HB-2002, Fermilab, IL, AIP Conf. Proc. 642:146-149 (2003)

19. *A Parallel Code for Lifetime Simulations in Hadron Storage Rings in the Presence of Parasitic Weak-Strong Beam-Beam Interactions*, with A. Kabel, Y. Cai, T. Sen and M. Xiao, Proceedings of PAC 2003, Portland, OR (2003)

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15. *Analytic Studies of the Long-Range Beam-Beam Tune Shifts and Chromaticities*, with T. Sen, FERMILAB-CONF-02-131-T, Proceedings of EPAC 2002, Paris, France (2002)

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11. *Towards Accurate Simulation of Fringe Field Effects*, with M. Berz and K. Makino, Nuclear Instruments and Methods **A**, **472** (2001) 533-540

10. *Fringe Fields and Dynamic Aperture in the FNAL Muon Storage Ring*, with F. Zimmermann, C. Johnstone, M. Berz, K. Makino, and W. Wan, Technical Report CERN, SL-2000-011 AP and NUFACT-NOTE 21 (2000)

9. *Fringe field effects in Muon Rings*, with M. Berz and K. Makino, Proceedings of HEMC'99, Workshop on Muon Colliders at Highest Energies, Montauk, Long Island (1999)

8. *Detailed Analysis of Fringe Field Effects in the Large Hadron Collider*, with M. Berz and K. Makino, Technical Report MSUCL-1129 (1999)

7. *Time-of-Flight Mass Spectra From Ion Packets Generated on the Front of Deflecting Pulses*, with D. Ioanoviciu, C. Cuna, A. Pamula, N. Palibroda, V. Cosma, St. Kovacs, St. Popescu, M. Kaucsar, L. Sarkozy, D. Ursu, and P. Ardelean, Proceedings of Isotopic and Molecular Processes Conference, National Institute for Research and Development of Isotopic and Molecular Technologies, Cluj-N., Romania (1999), to appear in Studia Universitatis Babes-Bolyai, Physica series (2001)

6. *Differential Algebraic Determination of High-Order Off-Energy Closed Orbits, Chromaticities, and Momentum Compactions*, with M. Berz, W. Wan, and K.Y. Ng, Nuclear Instruments and Methods, **A 427**, 310-314 (1999).

5. *The Influence of Fringe Fields on Particle Dynamics in the Large Hadron Collider*, with W. Wan, C. Johnstone, J. Holt, M. Berz, K. Makino, and M. Lindemann, Nuclear Instruments and Methods, **A 427**, 74-78 (1999).

4. *The Differential Algebraic and Analytic Calculation of Momentum Compaction and Comparison with Tracking Codes and COSY Infinity*, with M. Berz, W. Wan, and K.Y. Ng, Technical Report MSUCL-1096 (1998)

3. *Lie Algebraic Theory of Transfer Matrices in Ion Optics of Mass Spectrometers***,** Rapid Communications in Mass Spectrometry, **10,** 1001-1012 (1996)

2. *Lie Algebraic Methods for Non-linear Dynamics of Charged Particles in Electromagnetic Fields* (in Romanian), Annals of University of Oradea (1996)

1. *Time Focusing Magnetic Wedge-field Sectors for Time-Resolved Ion Momentum Spectrometry***,** with D. Ioanoviciu, M.I. Yavor and C. Cuna, Rapid Communications in Mass Spectrometry, **9,** 1239-1240 (1995)

Biographical Sketch 3

Kyoko Makino
Department of Physics and Astronomy, Michigan State University

DATE OF BIRTH: January 1, 1959

DEGREES AWARDED:

B.S., Physics, Nagoya University	1981
M.S., Physics, Nagoya University	1983
Ph.D., Physics, Michigan State University	1998

APPOINTMENTS:

2004-present	Associate Professor of Physics, Michigan State University
2003-2004	Adjunct Professor of Physics, Michigan State University
2001-2004	Visiting Research Associate Professor of Physics, University of Illinois at Urbana-Champaign
1998-2001	Postdoctoral Appointment, Michigan State University
1988-1992	Staff Scientist, Information and Mathematical Science Laboratory, Tokyo, Japan

Kyoko Makino

Selected Publications Related to this proposal

K. Makino and M. Berz. “COSY INFINITY Version 7,” AIP CP, **391** (1996) 253.

K. Makino and M. Berz. “COSY INFINITY Version 8,” NIM **A427** (1999) 338-343.

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M. Berz, B. Erdélyi, and K. Makino. “Towards Accurate Simulation of Fringe Field Effects,” NIM **A472** , 3 (2001) 533-540.

M. Berz and K. Makino. “COSY INFINITY Version 8.1 - User's Guide and Reference Manual,” Technical Report MSUHEP-20704, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, (2001).

M. Berz, J. Hoefkens, and K. Makino. “COSY INFINITY Version 8.1 - Programming Manual,” Technical Report MSUHEP-20703, Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, (2001).

K. Makino, B. Erdélyi, and M. Berz. “Magnet Fringe Fields, Nonlinear Effects, and Compensation in Large Acceptance Rings,” in 2001 Particle Accelerator Conference. IEEE, (2001).

K. Makino, D. Errede, and M. Berz. “Cooling Channel Simulations based on Map Methods,” in Proc. of the APS/DPF/DPB Summer Study on the Future of Particle Physics (Snowmass 2001), (2002) T702.

A. A. Geraci, T. A. Barlow, M. Portillo, J. A. Nolen, K. W. Shepard, K. Makino, and M. Berz, “High-Order Maps with Acceleration for Optimization of Electrostatic and Radio-Frequency Ion-Optical Elements,” Rev. Sci. Instrum. **73** (2002) 3174-3180.

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C. J. Johnstone, M. Berz, D. Errede, and K. Makino. “Muon Beam Ionization Cooling in a Linear Quadrupole Channel,” NIM **A519** (2004) 472-482.

D. Errede, K. Makino, M. Berz, C. J. Johnstone, and A. van Ginneken. “Stochastic Processes in Muon Ionization Cooling,” NIM **A519** (2004) 466-471.

C. O. Maidana, M. Berz, and K. Makino. “Muon Beam Ring Cooler Simulations using COSY INFINITY,” IOP CP, **175** (2004) 211-218.

K. Makino and M. Berz. “Tetra Cooler Ring Simulation in COSY INFINITY,” NuFact03, AIP CP (2004) in print.

M. Berz, K. Makino, and C.J. Johnstone. “Propagation of a Large-Emittance Muon Beam through a Straight, Quadrupole-based Precooling Channel,” NuFact03, AIP CP (2004) in print.

Description of Facilities and Resources

The present proposal brings together expertise in fragment separator and magnetic spectrometer design, including high order optics and numerical optimization. To carry out the simulation work computer clusters are available at both sites, Argonne National Laboratory and Michigan State University.

Letters of intent to collaborate

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October 13, 2004

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To Whom It May Concern:

This letter is to express my intent to collaborate with Dr. Jerry Nolen of Argonne National Laboratory and Prof. Kyoko Makino of Michigan State University on development of simulation tools and designs of the Fragment Separators for the proposed Rare Isotope Accelerator (RIA).

The proposed work includes the extension of the code COSY Infinity that will allow the accurate simulation of the ion optics including beam-material interactions and high order optimization, and consideration of various possible options for the layouts and performances of fragment separators.

We feel that the combined expertise of the people involved in this project is the most efficient way in finding the optimal designs in a cost-effective manner that will maximize the benefit to RIA and the whole scientific community in general.

Sincerely yours,

Bela Erdelyi

Bela Erdelyi
Assistant Professor

MICHIGAN STATE
UNIVERSITY

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Associate Professor of Physics
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Michigan State University
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October 20, 2004

To Whom It May Concern:

This letter is to express our intent to collaborate with Jerry Nolen of Argonne National Laboratory and Bela Erdelyi of Northern Illinois University as well as other personnel on aspects of the design of the fragment separators at RIA and the development of simulation codes necessary for such design tasks.

The continued work on the RIA concept at the current stage much depends on the detailed analysis and perfection of the design of the fragment separators, which in turn requires accurate and efficient simulation. The various frontier requirements of such designs demand the use of state-of-the-art tools as well as the development of new schemes and tools for simulation codes. We believe that such a frontier task is most cost efficiently performed by gathering the expertise from various respective centers. The ANL group, being intimately familiar with the requirements of the RIA concept, will work on design optimization while providing specifications for the high order design code necessary for the analysis of such devices. The MSU group, specialized in the development of new tools and approaches for beam optics codes, will work on implementation of the schemes and methods deemed necessary for the simulation effort, provide support, and lead the code verification effort.

Sincerely yours,

Kyoko Makino

Kyoko Makino
Associate Professor of Physics

MICHIGAN STATE
UNIVERSITY

8 October 2004

To Whom It May Concern:

This letter is to express our intent to collaborate with J.A. Nolen Jr. et al. on the development of the design for the fragment separators at RIA and in the development of simulation codes for these designs. This work is central to the RIA concept. The goal of high collection efficiency, high selectivity, and the use of thick production targets pushes the state of the art in ion-optical design and will require a concerted effort on many fronts. Verified simulation codes are needed for ion-optical calculations to at least 5^{th} order and fast modeling codes that include all aspects of rare-isotope production; secondary interactions and ion interaction with materials are also necessary. In the design process we must also consider operational constraints so that the facility can be operated in a safe and reliable manor. Finally, alternatives must be explored and agreement must be reached on the most effective configuration that meets the RIA design requirements.

We feel that coordinated efforts on the fragment separator design will lead to the most cost effective and reliable solutions. The ANL group will lead in the development of high-order design codes that can be used to optimize the design. The MSU group will work on code verification and the "end to end" simulation codes necessary to evaluate the ultimate beam purity and gas stopping efficiency. Both groups will explore alternatives to the base line separator layout. This includes layouts that are favorable to beam dumps and remote handing and are the subject of other research and development proposals. All ideas will be jointly shared and consideration will be taken so that no site-specific constraints are violated.

Sincerely,

David J. Morrissey
Professor of Chemistry

Bradley M. Sherrill
University Distinguished Professor of Physics

Oleg Tarasov
Physicist, National Superconducting Cyclotron Laboratory

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